Implementation of Modified ABC algorithm for optimizing Best Cost

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Abstract – The ABC (Artificial Bee Colony) algorithm is used for route search. In ABC, a colony of artificial forager bees (agents) searches for rich artificial food sources (good solutions for a given problem). The research paper elaborates upon the working principle of the Artificial Bee Colony algorithm. The ABC algorithm has been modified and implemented in the research paper. The paper performs the comparative analysis between existing ABC and modified ABC. The Best Cost parameter has been considered to evaluate the performance of the ABC and the modified ABC algorithm. MATLAB has been used as an implementing tool. Three cases with a different number of iterations have been implemented to calculate the Best Cost in each case. The obtained results have been compared and it is found that the value of Best Cost has been reduced in modified ABC for each case.

Keywords – Artificial Bee Colony algorithm, Bees, Best Cost, optimization.

I. INTRODUCTION

Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Dervis Karaboga in 2005, motivated by the intelligent behavior of honey bees [1, 2]. It is as simple as Particle Swarm Optimization (PSO) and Differential Evolution (DE) algorithms and uses only common control parameters such as colony size and maximum cycle number [3, 4]. ABC as an optimization tool, provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar [5, 6]. In the ABC system, artificial bees fly around in a multidimensional search space and some (employed and onlooker bees) choose food sources depending on the experience of themselves and their nestmates, and adjust their positions. Some (scouts) fly and choose the food sources randomly without using experience [7, 8, 9]. If the nectar amount of a new source is higher than that of the previous one in their memory, they memorize the new position and forget the previous one [10, 11, 12]. Thus, the ABC system combines local search methods, carried out by employed and onlooker bees, with global search methods, managed by onlookers and scouts, attempting to balance exploration and exploitation process [13, 14, 15].

II. IMPLEMENTATION OF ABC

This section elaborates on the implementation performed to calculate the best cost involved in finding the best path from source to destination using the ABC algorithm.

Different parameters considered in calculating the best cost are mentioned as under.

- dv - Number of decision variables
- lbdv - Lower Bound of Decision Variables
- ubdv - Upper Bound of Decision Variables
- maxitr - Refers to the maximum number of iterations
- nsb - Number of scout Bees
- nss - Number of selected sites
- nes - Number of selected Elite sites
- nssb - Number of recruited bees for selected sites
- nesb - Number of Recruited Bees for Elite Sites
- nghbr - Neighborhood Radius
- nghbrdmp - Neighborhood Radius damp rate

Case 1:

The readings assigned to different parameters are given below.

- dv = 5
- lbdv = -20
- ubdv = 20
- maxitr = 1000
- nsb = 60
- nss = round (0.5 * nsb) = 30
- nes = round (0.4 * nss) = 12
- nssb = round(0.5 * nsb) = 30
- nesb = 2 * nssb = 60
- nghbr = 0.1*(ubdv-lbdv)
- nghbrdmp = 0.95

The best cost reading of the first 30 iterations as per the values of parameters mentioned in Case 1 above are shown in Fig. 1.

```
Iteration 1: Best Cost = 81.1738
Iteration 2: Best Cost = 49.0143
Iteration 3: Best Cost = 29.8862
Iteration 4: Best Cost = 12.1856
Iteration 5: Best Cost = 5.1712
Iteration 6: Best Cost = 2.4994
Iteration 7: Best Cost = 0.20685
Iteration 8: Best Cost = 0.030257
Iteration 9: Best Cost = 0.00065934
Iteration 10: Best Cost = 0.00031837
Iteration 11: Best Cost = 0.00017042
Iteration 12: Best Cost = 0.00017042
Iteration 13: Best Cost = 9.2782e-05
Iteration 14: Best Cost = 7.7955e-05
Iteration 15: Best Cost = 6.7517e-05
Iteration 16: Best Cost = 3.3251e-05
Iteration 17: Best Cost = 3.0102e-05
Iteration 18: Best Cost = 1.7897e-06
Iteration 19: Best Cost = 1.7897e-06
Iteration 20: Best Cost = 1.7897e-06
Iteration 21: Best Cost = 1.1253e-06
Iteration 22: Best Cost = 1.1253e-06
Iteration 23: Best Cost = 1.1253e-06
Iteration 24: Best Cost = 1.1253e-06
Iteration 25: Best Cost = 8.8306e-07
Iteration 26: Best Cost = 8.8306e-07
Iteration 27: Best Cost = 8.8306e-07
Iteration 28: Best Cost = 8.8306e-07
Iteration 29: Best Cost = 8.8306e-07
Iteration 30: Best Cost = 8.8306e-07
```

Fig. 1. The figure shows the obtained readings of Best Cost in case of first 30 iterations

The best cost reading of the last 30 iterations as per the values of parameters mentioned in Case 1 above are shown in Fig. 2.

```
Iteration 970: Best Cost = 1.2421e-49
Iteration 971: Best Cost = 1.2421e-49
Iteration 972: Best Cost = 1.2421e-49
Iteration 973: Best Cost = 1.2421e-49
Iteration 974: Best Cost = 1.2421e-49
Iteration 975: Best Cost = 1.2421e-49
Iteration 976: Best Cost = 1.2421e-49
Iteration 977: Best Cost = 1.2421e-49
Iteration 978: Best Cost = 1.2421e-49
Iteration 979: Best Cost = 1.2421e-49
Iteration 980: Best Cost = 1.2421e-49
Iteration 981: Best Cost = 1.2421e-49
Iteration 982: Best Cost = 1.2421e-49
Iteration 983: Best Cost = 1.2421e-49
Iteration 984: Best Cost = 1.2421e-49
Iteration 985: Best Cost = 4.0691e-50
Iteration 986: Best Cost = 4.0691e-50
Iteration 987: Best Cost = 4.0691e-50
Iteration 988: Best Cost = 4.0691e-50
Iteration 989: Best Cost = 4.0691e-50
Iteration 990: Best Cost = 4.0691e-50
Iteration 991: Best Cost = 4.0691e-50
Iteration 992: Best Cost = 4.0691e-50
Iteration 993: Best Cost = 2.3923e-50
Iteration 994: Best Cost = 2.3923e-50
Iteration 995: Best Cost = 2.3923e-50
Iteration 996: Best Cost = 2.3923e-50
Iteration 997: Best Cost = 2.3923e-50
Iteration 998: Best Cost = 2.3923e-50
Iteration 999: Best Cost = 2.3923e-50
Iteration 1000: Best Cost = 2.3923e-50
```

Fig. 2. The figure shows the obtained readings of Best Cost in case of last 30 iterations

The graph is shown in Fig. 3 clearly indicates the reduction in the value of Best Cost as the number of iterations increased. The Best Cost reading obtained in the case of the first iteration is 81.1738 and the one obtained in 1000th iteration is 2.3923e-50.

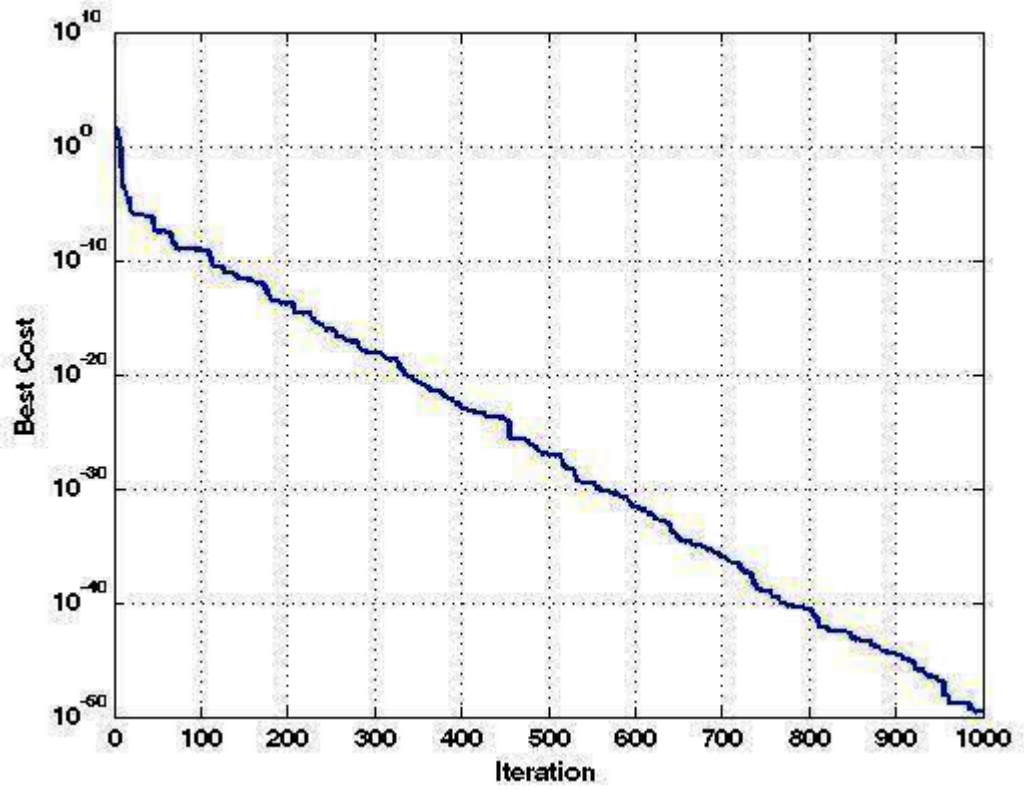

Fig. 3. The figure shows the graphical representation of obtained Best Cost (Y-axis) against the number of iterations (X-axis)

Case 2:

The readings assigned to different parameters are given below.

- dv = 5
- lbdv = -20
- ubdv = 20
- maxitr = 2000
- nsb = 60
- nss = round (0.5 * nsb) = 30
- nes = round (0.4 * nss) = 12
- nssb = round(0.5 * nsb) = 30
- nesb = 2 * nssb = 60
- nghbr = 0.1*(ubdv-lbdv)
- nghbrdmp = 0.95

The best cost reading of the first 30 iterations as per the values of parameters mentioned in Case 2 above are shown in Fig. 4.

```
Iteration 1: Best Cost = 36.9224
Iteration 2: Best Cost = 25.9283
Iteration 3: Best Cost = 15.6721
Iteration 4: Best Cost = 9.2611
Iteration 5: Best Cost = 6.0796
Iteration 6: Best Cost = 3.6314
Iteration 7: Best Cost = 1.8329
Iteration 8: Best Cost = 0.76825
Iteration 9: Best Cost = 0.062974
Iteration 10: Best Cost = 0.021118
Iteration 11: Best Cost = 0.0019943
Iteration 12: Best Cost = 0.00040972
Iteration 13: Best Cost = 0.0002253
Iteration 14: Best Cost = 0.00010183
Iteration 15: Best Cost = 5.1315e-05
Iteration 16: Best Cost = 2.3791e-05
Iteration 17: Best Cost = 4.3477e-06
Iteration 18: Best Cost = 2.3829e-06
Iteration 19: Best Cost = 1.1234e-06
Iteration 20: Best Cost = 9.0092e-07
Iteration 21: Best Cost = 9.0092e-07
Iteration 22: Best Cost = 7.1738e-07
Iteration 23: Best Cost = 7.1738e-07
Iteration 24: Best Cost = 7.1738e-07
Iteration 25: Best Cost = 4.9737e-07
Iteration 26: Best Cost = 4.9737e-07
Iteration 27: Best Cost = 4.9737e-07
Iteration 28: Best Cost = 4.9737e-07
Iteration 29: Best Cost = 4.9737e-07
Iteration 30: Best Cost = 4.9737e-07
```

Fig. 4. The figure shows the obtained readings of Best Cost in case of first 30 iterations

The best cost reading of the last 30 iterations as per the values of parameters mentioned in Case 2 above are shown in Fig. 5.

```
Iteration 1970: Best Cost = 1.8314e-94
Iteration 1971: Best Cost = 1.8314e-94
Iteration 1972: Best Cost = 1.8314e-94
Iteration 1973: Best Cost = 1.8178e-94
Iteration 1974: Best Cost = 1.8178e-94
Iteration 1975: Best Cost = 1.8178e-94
Iteration 1976: Best Cost = 1.8178e-94
Iteration 1977: Best Cost = 1.8178e-94
Iteration 1978: Best Cost = 1.8178e-94
Iteration 1979: Best Cost = 1.8178e-94
Iteration 1980: Best Cost = 3.7112e-95
Iteration 1981: Best Cost = 3.7112e-95
Iteration 1982: Best Cost = 3.565e-95
Iteration 1983: Best Cost = 3.565e-95
Iteration 1984: Best Cost = 2.715e-95
Iteration 1985: Best Cost = 2.715e-95
Iteration 1986: Best Cost = 2.715e-95
Iteration 1987: Best Cost = 2.715e-95
Iteration 1988: Best Cost = 2.6553e-95
Iteration 1989: Best Cost = 2.6553e-95
Iteration 1990: Best Cost = 2.6553e-95
Iteration 1991: Best Cost = 2.6553e-95
Iteration 1992: Best Cost = 2.6553e-95
Iteration 1993: Best Cost = 2.6553e-95
Iteration 1994: Best Cost = 2.6553e-95
Iteration 1995: Best Cost = 2.6553e-95
Iteration 1996: Best Cost = 2.519e-95
Iteration 1997: Best Cost = 2.519e-95
Iteration 1998: Best Cost = 2.519e-95
Iteration 1999: Best Cost = 2.519e-95
Iteration 2000: Best Cost = 2.519e-95
```

Fig. 5. The figure shows the obtained readings of Best Cost in case of last 30 iterations

The graph shown in Fig. 6 clearly indicates the reduction in the value of Best Cost as the number of iterations increased. The Best Cost reading obtained in the case of the first iteration is 36.9224 and the one obtained in 2000^{th} iteration is 2.519e-95.

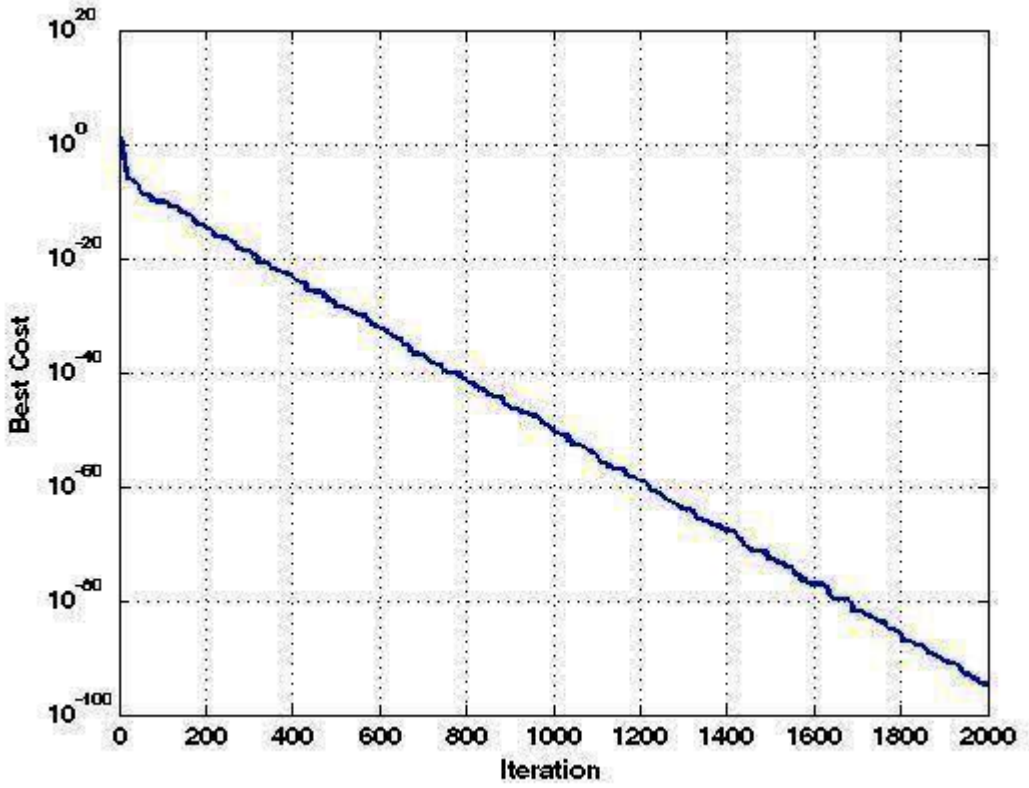

Fig. 6. The figure shows the graphical representation of obtained Best Cost (Y-axis) against number of iterations (X-axis)

Case 3:

The readings assigned to different parameters are given below.

- dv = 5
- lbdv = -20
- ubdv = 20
- maxitr = 3000
- nsb = 60
- nss = round (0.5 * nsb) = 30
- nes = round (0.4 * nss) = 12
- nssb = round(0.5 * nsb) = 30
- nesb = 2 * nssb = 60
- nghbr = 0.1*(ubdv-lbdv)
- nghbrdmp = 0.95

The best cost reading of first 30 iterations as per the values of parameters mentioned in Case 3 above are shown in Fig. 7.

```
Iteration 1: Best Cost = 21.1082
Iteration 2: Best Cost = 13.2402
Iteration 3: Best Cost = 6.8979
Iteration 4: Best Cost = 0.91806
Iteration 5: Best Cost = 0.16154
Iteration 6: Best Cost = 0.080503
Iteration 7: Best Cost = 0.0097819
Iteration 8: Best Cost = 0.0070149
Iteration 9: Best Cost = 0.0043479
Iteration 10: Best Cost = 0.0019183
Iteration 11: Best Cost = 0.0015089
Iteration 12: Best Cost = 0.0008391
Iteration 13: Best Cost = 0.00061524
Iteration 14: Best Cost = 0.00025415
Iteration 15: Best Cost = 5.7541e-05
Iteration 16: Best Cost = 5.7541e-05
Iteration 17: Best Cost = 3.7825e-05
Iteration 18: Best Cost = 2.0963e-05
Iteration 19: Best Cost = 2.0963e-05
Iteration 20: Best Cost = 1.8749e-05
Iteration 21: Best Cost = 1.8749e-05
Iteration 22: Best Cost = 5.4297e-06
Iteration 23: Best Cost = 4.6884e-06
Iteration 24: Best Cost = 4.6884e-06
Iteration 25: Best Cost = 4.6884e-06
Iteration 26: Best Cost = 4.6884e-06
Iteration 27: Best Cost = 3.0791e-06
Iteration 28: Best Cost = 3.0791e-06
Iteration 29: Best Cost = 3.0507e-06
Iteration 30: Best Cost = 3.0507e-06
```

Fig. 7. The figure shows the obtained readings of Best Cost in case of first 30 iterations

The best cost reading of last 30 iterations as per the values of parameters mentioned in Case 3 above are shown in Fig. 8.

```
Iteration 2970: Best Cost = 4.9395e-138
Iteration 2971: Best Cost = 4.9395e-138
Iteration 2972: Best Cost = 4.9395e-138
Iteration 2973: Best Cost = 4.9395e-138
Iteration 2974: Best Cost = 4.9395e-138
Iteration 2975: Best Cost = 4.4552e-138
Iteration 2976: Best Cost = 4.4552e-138
Iteration 2977: Best Cost = 4.4552e-138
Iteration 2978: Best Cost = 4.4552e-138
Iteration 2979: Best Cost = 1.075e-138
Iteration 2980: Best Cost = 1.075e-138
Iteration 2981: Best Cost = 1.075e-138
Iteration 2982: Best Cost = 1.075e-138
Iteration 2983: Best Cost = 1.075e-138
Iteration 2984: Best Cost = 1.0355e-138
Iteration 2985: Best Cost = 1.0355e-138
Iteration 2986: Best Cost = 1.0222e-138
Iteration 2987: Best Cost = 9.8426e-139
Iteration 2988: Best Cost = 9.8426e-139
Iteration 2989: Best Cost = 9.8426e-139
Iteration 2990: Best Cost = 9.7846e-139
Iteration 2991: Best Cost = 9.7846e-139
Iteration 2992: Best Cost = 9.7846e-139
Iteration 2993: Best Cost = 9.7846e-139
Iteration 2994: Best Cost = 9.7846e-139
Iteration 2995: Best Cost = 9.7846e-139
Iteration 2996: Best Cost = 9.7846e-139
Iteration 2997: Best Cost = 9.7846e-139
Iteration 2998: Best Cost = 9.7846e-139
Iteration 2999: Best Cost = 9.7846e-139
Iteration 3000: Best Cost = 4.1892e-139
```

Fig. 8. The figure shows the obtained readings of Best Cost in case of last 30 iterations

The graph shown in Fig. 9 clearly indicates the reduction in the value of Best Cost as the number of iterations increased. The Best Cost reading obtained in the case of the first iteration is 21.1082 and the one obtained in 3000^{th} iteration is 4.1892e-139.

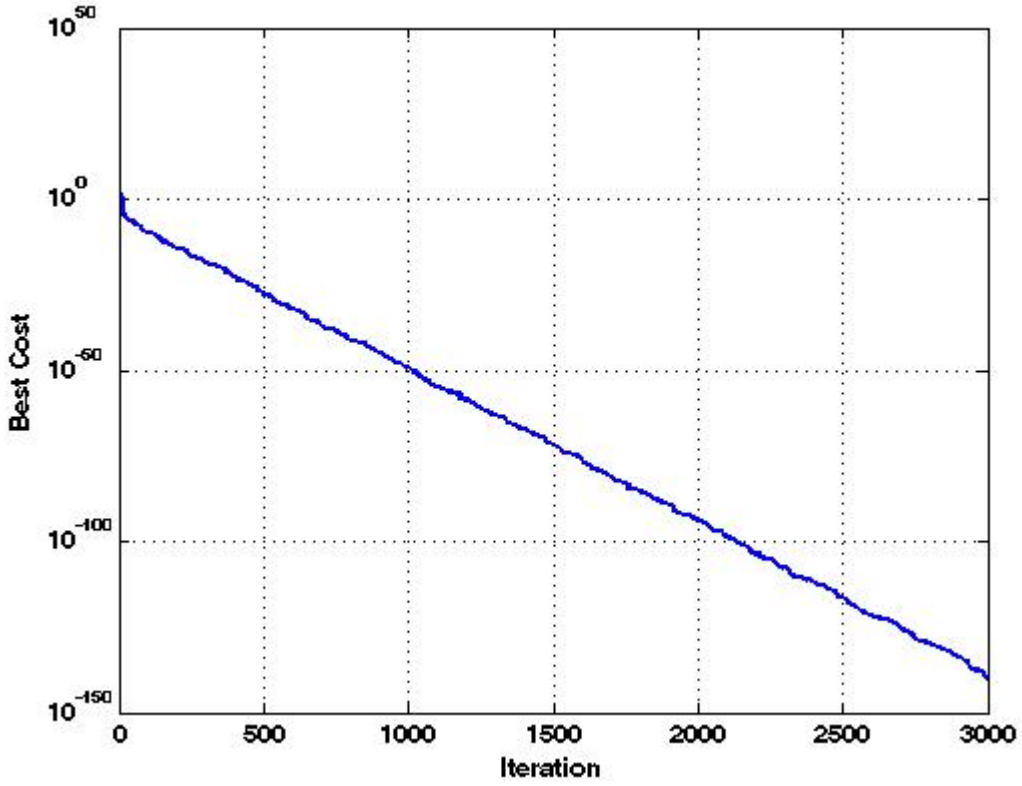

Fig. 9. The figure shows the graphical representation of obtained Best Cost (Y-axis) against the number of iterations (X-axis)

III. IMPLEMENTATION OF MODIFIED ABC

This section elaborates on the implementation performed to calculate the best cost involved in finding the best path from source to destination using the modified ABC algorithm. The three cases with the same readings as were in section II have been implemented.

Case 1:

The readings assigned to different parameters are given below.

- dv = 5
- lbdv = -20
- ubdv = 20
- maxitr = 1000
- nsb = 60
- nss = round (0.5 * nsb) = 30
- nes = round (0.4 * nss) = 12
- nssb = round(0.5 * nsb) = 30
- nesb = 2 * nssb = 60
- nghbr = 0.1*(ubdv-lbdv)
- nghbrdmp = 0.95

The best cost reading of first 30 iterations as per the values of parameters mentioned in Case 1 above are shown in Fig. 10.

```
Iteration 1: Best Cost = 56.6651
Iteration 2: Best Cost = 24.5286
Iteration 3: Best Cost = 14.2169
Iteration 4: Best Cost = 8.7222
Iteration 5: Best Cost = 1.6838
Iteration 6: Best Cost = 0.84509
Iteration 7: Best Cost = 0.011703
Iteration 8: Best Cost = 0.0064624
Iteration 9: Best Cost = 0.0028796
Iteration 10: Best Cost = 0.00030349
Iteration 11: Best Cost = 0.00011645
Iteration 12: Best Cost = 5.9523e-05
Iteration 13: Best Cost = 3.5144e-05
Iteration 14: Best Cost = 3.0516e-05
Iteration 15: Best Cost = 1.7648e-05
Iteration 16: Best Cost = 1.7648e-05
Iteration 17: Best Cost = 8.0653e-06
Iteration 18: Best Cost = 8.0653e-06
Iteration 19: Best Cost = 6.3552e-06
Iteration 20: Best Cost = 5.2671e-06
Iteration 21: Best Cost = 4.0663e-06
Iteration 22: Best Cost = 4.0448e-06
Iteration 23: Best Cost = 4.0448e-06
Iteration 24: Best Cost = 8.7508e-07
Iteration 25: Best Cost = 8.088e-07
Iteration 26: Best Cost = 8.088e-07
Iteration 27: Best Cost = 3.3808e-07
Iteration 28: Best Cost = 3.3808e-07
Iteration 29: Best Cost = 3.3808e-07
Iteration 30: Best Cost = 3.3808e-07
```

Fig. 10. The figure shows the obtained readings of Best Cost in case of first 30 iterations

The best cost reading of the last 30 iterations as per the values of parameters mentioned in Case 1 above are shown in Fig. 11.

```
Iteration 970: Best Cost = 2.1154e-49
Iteration 971: Best Cost = 2.0834e-49
Iteration 972: Best Cost = 2.0834e-49
Iteration 973: Best Cost = 2.0834e-49
Iteration 974: Best Cost = 2.0834e-49
Iteration 975: Best Cost = 2.0834e-49
Iteration 976: Best Cost = 2.0834e-49
Iteration 977: Best Cost = 2.0834e-49
Iteration 978: Best Cost = 1.6864e-49
Iteration 979: Best Cost = 1.6864e-49
Iteration 980: Best Cost = 1.6864e-49
Iteration 981: Best Cost = 1.6864e-49
Iteration 982: Best Cost = 1.6864e-49
Iteration 983: Best Cost = 1.6864e-49
Iteration 984: Best Cost = 1.6864e-49
Iteration 985: Best Cost = 1.6864e-49
Iteration 986: Best Cost = 1.6864e-49
Iteration 987: Best Cost = 1.6798e-49
Iteration 988: Best Cost = 1.5453e-49
Iteration 989: Best Cost = 1.514e-49
Iteration 990: Best Cost = 2.4628e-50
Iteration 991: Best Cost = 2.4628e-50
Iteration 992: Best Cost = 2.4628e-50
Iteration 993: Best Cost = 2.4628e-50
Iteration 994: Best Cost = 2.4628e-50
Iteration 995: Best Cost = 2.4628e-50
Iteration 996: Best Cost = 2.4628e-50
Iteration 997: Best Cost = 1.8902e-50
Iteration 998: Best Cost = 1.8902e-50
Iteration 999: Best Cost = 1.8902e-50
Iteration 1000: Best Cost = 1.8902e-50
```

Fig. 11. The figure shows the obtained readings of Best Cost in case of last 30 iterations

The graph is shown in Fig. 12 clearly indicates the reduction in the value of Best Cost as the number of iterations increased. The Best Cost reading obtained in the case of the first iteration is 56.6651 and the one obtained in 1000^{th} iteration is 1.8902e-50.

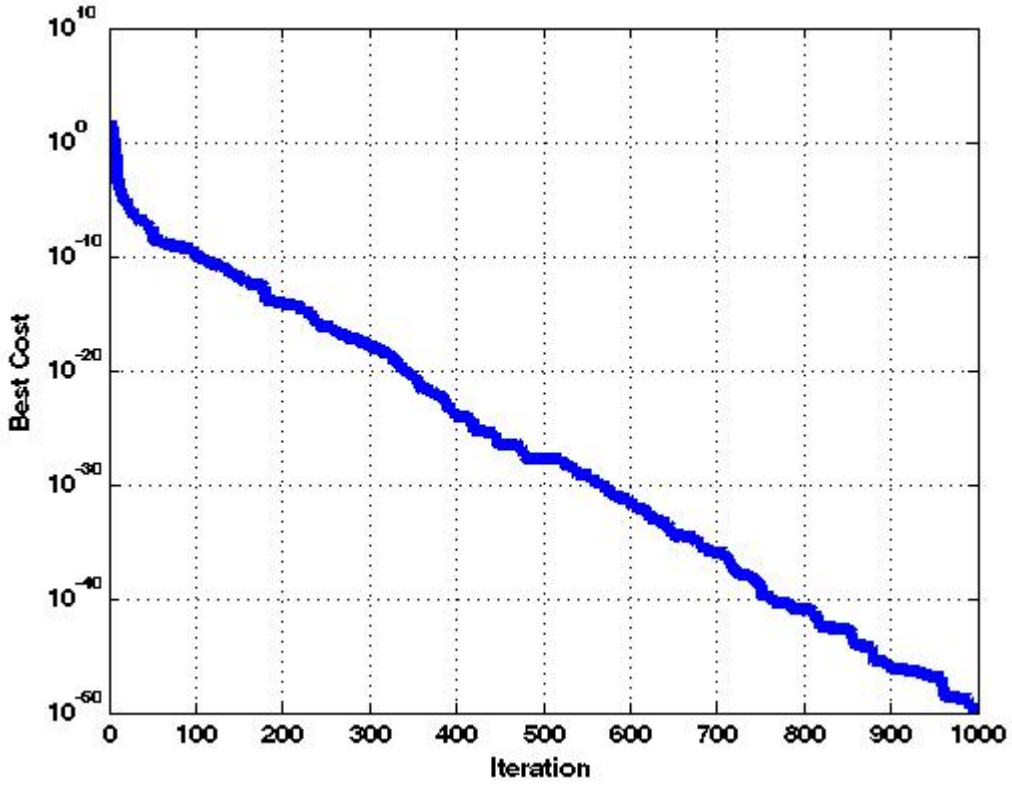

Fig. 12. The figure shows the graphical representation of obtained Best Cost (Y-axis) against the number of iterations (X-axis)

Case 2:

The readings assigned to different parameters are given below.

- dv = 5
- lbdv = -20
- ubdv = 20
- maxitr = 2000
- nsb = 60
- nss = round (0.5 * nsb) = 30
- nes = round (0.4 * nss) = 12
- nssb = round(0.5 * nsb) = 30
- nesb = 2 * nssb = 60
- nghbr = 0.1*(ubdv-lbdv)
- nghbrdmp = 0.95

The best cost reading of the first 30 iterations as per the values of parameters mentioned in Case 1 above are shown in Fig. 13.

```
Iteration 1: Best Cost = 99.5258
Iteration 2: Best Cost = 51.5493
Iteration 3: Best Cost = 29.2178
Iteration 4: Best Cost = 12.4963
Iteration 5: Best Cost = 5.9646
Iteration 6: Best Cost = 3.1494
Iteration 7: Best Cost = 1.1386
Iteration 8: Best Cost = 0.54985
Iteration 9: Best Cost = 0.00377
Iteration 10: Best Cost = 0.0024728
Iteration 11: Best Cost = 0.0013722
Iteration 12: Best Cost = 0.00043713
Iteration 13: Best Cost = 0.000423
Iteration 14: Best Cost = 0.00023303
Iteration 15: Best Cost = 0.00018331
Iteration 16: Best Cost = 1.3488e-05
Iteration 17: Best Cost = 1.1922e-05
Iteration 18: Best Cost = 1.1922e-05
Iteration 19: Best Cost = 1.1922e-05
Iteration 20: Best Cost = 8.9142e-06
Iteration 21: Best Cost = 8.9142e-06
Iteration 22: Best Cost = 8.9142e-06
Iteration 23: Best Cost = 8.9142e-06
Iteration 24: Best Cost = 5.1636e-06
Iteration 25: Best Cost = 5.1636e-06
Iteration 26: Best Cost = 4.6668e-06
Iteration 27: Best Cost = 1.9468e-06
Iteration 28: Best Cost = 1.28e-06
Iteration 29: Best Cost = 1.28e-06
Iteration 30: Best Cost = 1.28e-06
```

Fig. 13. The figure shows the obtained readings of Best Cost in case of first 30 iterations

The best cost reading of the last 30 iterations as per the values of parameters mentioned in Case 2 above are shown in Fig. 14.

```
Iteration 1970: Best Cost = 4.2098e-94
Iteration 1971: Best Cost = 4.2098e-94
Iteration 1972: Best Cost = 4.2098e-94
Iteration 1973: Best Cost = 4.2098e-94
Iteration 1974: Best Cost = 4.2098e-94
Iteration 1975: Best Cost = 4.2098e-94
Iteration 1976: Best Cost = 1.2764e-94
Iteration 1977: Best Cost = 1.2764e-94
Iteration 1978: Best Cost = 1.2764e-94
Iteration 1979: Best Cost = 1.2764e-94
Iteration 1980: Best Cost = 1.2764e-94
Iteration 1981: Best Cost = 1.2764e-94
Iteration 1982: Best Cost = 1.2764e-94
Iteration 1983: Best Cost = 1.2764e-94
Iteration 1984: Best Cost = 1.2764e-94
Iteration 1985: Best Cost = 1.2764e-94
Iteration 1986: Best Cost = 1.2764e-94
Iteration 1987: Best Cost = 1.2764e-94
Iteration 1988: Best Cost = 6.9281e-95
Iteration 1989: Best Cost = 3.8938e-95
Iteration 1990: Best Cost = 3.8938e-95
Iteration 1991: Best Cost = 3.8938e-95
Iteration 1992: Best Cost = 3.8938e-95
Iteration 1993: Best Cost = 3.8938e-95
Iteration 1994: Best Cost = 3.2068e-95
Iteration 1995: Best Cost = 3.2068e-95
Iteration 1996: Best Cost = 3.0477e-95
Iteration 1997: Best Cost = 3.0477e-95
Iteration 1998: Best Cost = 3.0477e-95
Iteration 1999: Best Cost = 3.0477e-95
Iteration 2000: Best Cost = 1.8497e-95
```

Fig. 14. The figure shows the obtained readings of Best Cost in case of last 30 iterations

The graph is shown in Fig. 15 clearly indicates the reduction in the value of Best Cost as the number of iterations increased. The Best Cost reading obtained in the case of the first iteration is 99.5258 and the one obtained in 2000^{th} iteration is 1.8497e-95.

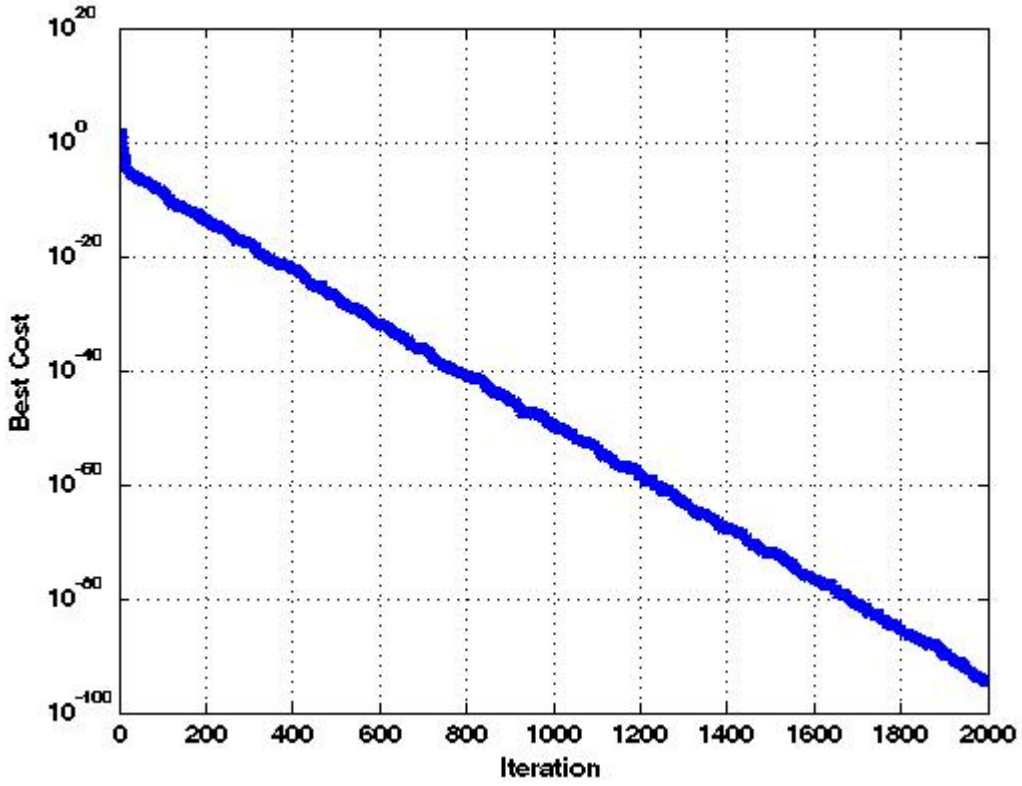

Fig. 15. The figure shows the graphical representation of obtained Best Cost (Y-axis) against the number of iterations (X-axis)

Case 3:

The readings assigned to different parameters are given below.

- dv = 5
- lbdv = -20
- ubdv = 20
- maxitr = 3000
- nsb = 60
- nss = round (0.5 * nsb) = 30
- nes = round (0.4 * nss) = 12
- nssb = round(0.5 * nsb) = 30
- nesb = 2 * nssb = 60
- nghbr = 0.1*(ubdv-lbdv)
- nghbrdmp = 0.95

The best cost reading of the first 30 iterations as per the values of parameters mentioned in Case 3 above are shown in Fig. 16.

```
Iteration 1: Best Cost = 98.9912
Iteration 2: Best Cost = 68.0943
Iteration 3: Best Cost = 40.3994
Iteration 4: Best Cost = 20.4768
Iteration 5: Best Cost = 13.0878
Iteration 6: Best Cost = 6.7242
Iteration 7: Best Cost = 1.8004
Iteration 8: Best Cost = 0.057918
Iteration 9: Best Cost = 0.013699
Iteration 10: Best Cost = 0.0062016
Iteration 11: Best Cost = 0.0010351
Iteration 12: Best Cost = 0.00050556
Iteration 13: Best Cost = 0.00013776
Iteration 14: Best Cost = 0.00013776
Iteration 15: Best Cost = 0.00012453
Iteration 16: Best Cost = 0.00012398
Iteration 17: Best Cost = 0.00011685
Iteration 18: Best Cost = 0.00011044
Iteration 19: Best Cost = 2.7319e-05
Iteration 20: Best Cost = 2.7319e-05
Iteration 21: Best Cost = 1.9896e-05
Iteration 22: Best Cost = 1.9896e-05
Iteration 23: Best Cost = 1.1795e-05
Iteration 24: Best Cost = 8.1577e-06
Iteration 25: Best Cost = 6.2305e-06
Iteration 26: Best Cost = 6.2305e-06
Iteration 27: Best Cost = 3.5933e-06
Iteration 28: Best Cost = 3.5933e-06
Iteration 29: Best Cost = 1.8861e-06
Iteration 30: Best Cost = 1.684e-06
```

Fig. 16. The figure shows the obtained readings of Best Cost in case of first 30 iterations

The best cost reading of the last 30 iterations as per the values of parameters mentioned in Case 3 above are shown in Fig. 17.

```
Iteration 2970: Best Cost = 1.6838e-137
Iteration 2971: Best Cost = 1.6838e-137
Iteration 2972: Best Cost = 1.6838e-137
Iteration 2973: Best Cost = 9.2097e-138
Iteration 2974: Best Cost = 4.4926e-138
Iteration 2975: Best Cost = 4.4926e-138
Iteration 2976: Best Cost = 4.4926e-138
Iteration 2977: Best Cost = 1.9855e-138
Iteration 2978: Best Cost = 1.7638e-138
Iteration 2979: Best Cost = 1.7638e-138
Iteration 2980: Best Cost = 1.6652e-138
Iteration 2981: Best Cost = 1.6652e-138
Iteration 2982: Best Cost = 1.6652e-138
Iteration 2983: Best Cost = 1.6652e-138
Iteration 2984: Best Cost = 1.6652e-138
Iteration 2985: Best Cost = 1.6652e-138
Iteration 2986: Best Cost = 9.3871e-139
Iteration 2987: Best Cost = 9.3281e-139
Iteration 2988: Best Cost = 9.3281e-139
Iteration 2989: Best Cost = 7.5988e-139
Iteration 2990: Best Cost = 1.7402e-139
Iteration 2991: Best Cost = 1.7402e-139
Iteration 2992: Best Cost = 1.7402e-139
Iteration 2993: Best Cost = 1.6677e-139
Iteration 2994: Best Cost = 1.6677e-139
Iteration 2995: Best Cost = 1.6677e-139
Iteration 2996: Best Cost = 1.6677e-139
Iteration 2997: Best Cost = 1.6677e-139
Iteration 2998: Best Cost = 1.6677e-139
Iteration 2999: Best Cost = 1.6677e-139
Iteration 3000: Best Cost = 1.6585e-139
```

Fig. 17. The figure shows the obtained readings of Best Cost in case of last 30 iterations

The graph is shown in Fig. 18 clearly indicates the reduction in the value of Best Cost as the number of iterations increased. The Best Cost reading obtained in the case of the first iteration is 98.9912 and the one obtained in 3000^{th} iteration is 1.6585e-139.

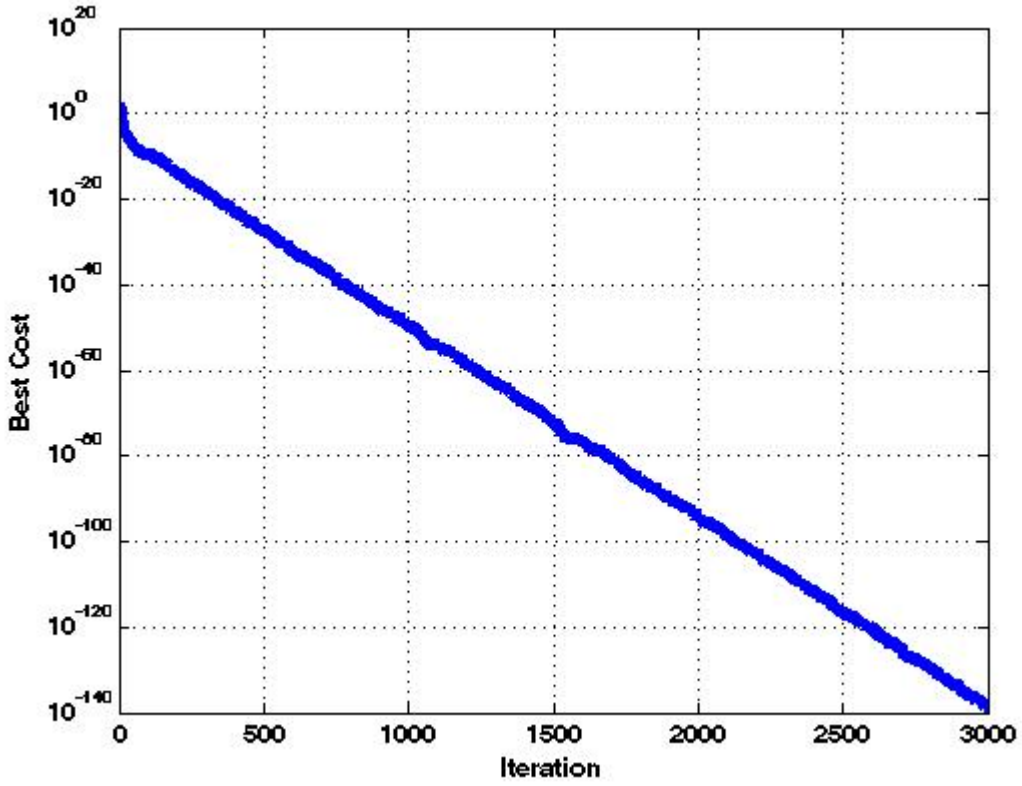

Fig. 18. The figure shows the graphical representation of obtained Best Cost (Y-axis) against the number of iterations (X-axis)

IV. CONCLUSION - BEST COST COMPARISON BETWEEN ABC AND MODIFIED ABC

Section II and section III of the research paper implemented the ABC and modified ABC respectively and obtained readings of the three cases studied. Table 1 below shows the final Best Cost obtained in the case of ABC and modified ABC under a different number of iterations.

Table 1. Best Cost readings of ABC and Modified ABC

No. of iterations	Best Cost (ABC)	Best Cost (Modified ABC)
1000	2.3923e-50	1.8902e-50
2000	2.519e-95	1.8497e-95
3000	4.1892e-139	1.6585e-139

The readings of Table 1 indicate that the proposed method has reduced the Best Cost in all three cases under study which proves the worth of research performed.

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